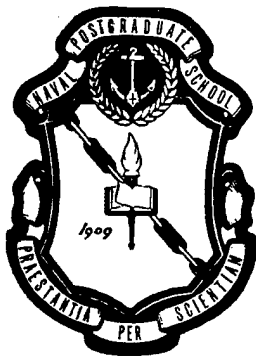


Naval Postgraduate School  
Monterey, California 93943-5138



# *SUMMARY OF RESEARCH 1995*

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**Monterey, California**

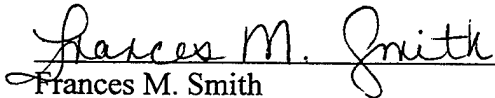
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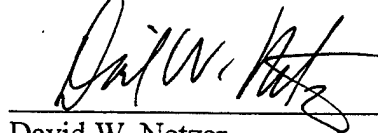
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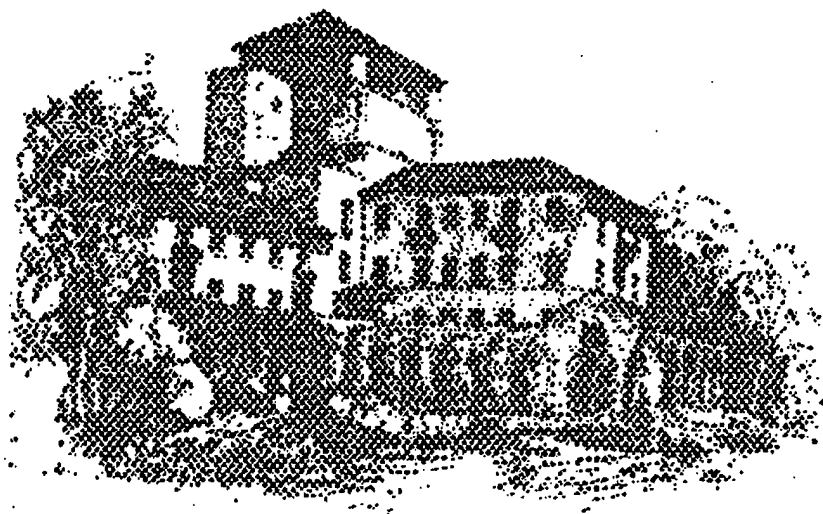
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## THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The School's focus is to increase the combat effectiveness of the armed forces of the United States by providing quality education which supports the unique needs of the defense establishment.



## Introduction

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.
- Keep faculty on the leading edge of advances in defense-related science, technology, management and policy to ensure that the latest information is incorporated into NPS courses and curricula.
- Apply faculty and student knowledge to enhance Navy/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

The overall research program at NPS has two funded components:

- The Direct Funded Research (DFR) Program provides internal funding from the School's operating budget to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.
- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The two research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

All research projects, both reimbursable and direct funded, support the School's research mission:

- To develop an overall research investment strategy that ensures a high quality, creative learning experience for NPS graduate students.
- To encourage faculty and student pursuit of new discoveries and applications which enhance the long term effectiveness of the armed forces.
- To stimulate interactions between NPS faculty and a wide variety of potential research sponsors (Government, Universities, Private Industry).
- To publicize (both internally and externally) significant achievements of the NPS research program and market NPS research capabilities.
- To foster synergy and force multiplication with Navy/DoD commands and laboratories to increase the potential for successful research and development programs

The Department of Physics has been a leader in introducing courses and curricula involving the applications of current technology to combat systems and the applications of science to problems of military interest. The Department offers courses, conducts research, and directs student theses in such areas as underwater detection and tracking, target detection and signature measurements, infrared countermeasures, combat systems design, combat systems simulation, directed energy weapons systems, electro-optic devices, and the influence of the atmosphere and near space environment on military systems. Historically, the Department has maintained the flexibility to move into new technological areas as they appear.

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During CY 1995, nineteen Physics Department faculty members participated in approximately 38 different research projects. Although the scope of these projects is quite broad, the research in the Physics Department can be grouped, for the purposes of this summary, into seven general areas: 1) Electromagnetic Radiation and Propagation Phenomena, 2) Remote Sensing, 3) Weapons/Shipboard Systems Technologies, 4) Ocean Acoustics and Air/Sea Interactions, 5) Combat Systems Technology and Policy, 6) Mine Warfare, and 7) Solid State Physics and Fundamental Processes. An overview of research activities in each of these areas follows.

## Electromagnetic Radiation and Propagation Phenomena

Professor **Donald Walters** is continuing work on atmospheric optical turbulence in support of the US Air Force Airborne Laser Program. He had the responsibility for developing a single probe, centimeter resolution, 0.001 K noise level, stratospheric probe system and flying the equipment in conjunction with the Airborne Laser Atmospheric Compensation Experiment. A probe package, balloon telemetry link and data reduction software were developed and deployed during March 1995 at McConnell AFB, Wichita, Kansas. The high resolution probe shows sharp temperature increases of 0.5 to 1 K over 1 - 2 m. These sharp temperature jumps are sufficiently abrupt to degrade the performance of laser systems with similar aperture sizes by introducing much higher beam wander and jitter than anticipated. A modeling effort is underway to determine the impact of these measurements.

Professor **Scott Davis** is continuing a multi-year project which has as its primary goal the development of a proof-of-concept prototype instrument capable of recording fully multiplexed images and multispectral images at long infrared wavelengths, where efficient focal plane array technology is not available. Most of this year's work centered around the CAD refinement of the designs for the reflecting-transmitting Walsh function basis masks and their optical substrates. The encoding mask systems were fabricated successfully, albeit in a larger format than was called for in the original plans for the instrument. This is requiring a rescaling of the prototype instrument's geometry and optics. Such unexpected glitches are not unreasonable in the development cycle of a new technology, as represented by this project. At the close of 1995, the requisite modifications to the optical and opto-mechanical designs of the prototype instrument were being conducted.

Professor **William Colson** continued to work in the area of free electron laser (FEL) simulations. His involvement included investigation of wavelength modulation and limit cycle behavior in FELs, atmospheric propagation simulations of high average power FELs, and ultraviolet FELs. He served as a member of the International Executive Subcommittee on Commentary on the National Academy of Science's National Research Council Committee on FELs and Other Advanced Coherent Light Sources, a member of the DOE Review Panel for the CEBAF/LPC Laser Processing Project, and chair of the Defense Applications Working Group for the CEBAF Laser Processing Consortium.

Professor **Alf Cooper** is continuing work in a number of areas related to the application of infrared technology to the Navy in support of the Naval Sea Systems Command (NAVSEA) and the Naval Command, Control and Ocean Surveillance Center (NCCOSC).

## Remote Sensing

Professor **David Cleary** is working in the area of remote sensing of the ionosphere. The goal of his project was to develop a passive technique for remote sensing the ionospheric electron density profile on a global basis, specifically to determine if the electron density can be inferred from the ultraviolet signature of the positive ions in the ionosphere. During 1995 they made significant progress on the development of a new technique for remote sensing of trace gases. The most notable was the progress made on the development of the NPS All-Reflection Michelson interferometer. In addition to instrument development, an analysis of the  $O^+$  834-Å emission was conducted to determine the feasibility of its use in ionospheric remote sensing. It was found that for nearly all altitudes this emission is sufficiently bright for this application.

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Professor **Chris Olsen** is working with Dr. **Phil Walker** on a project to analyze, and examine for correlations, aerosol and meteorological data taken at Edwards Air Force Base and the Naval Air Warfare Center, Weapons Division in 1990. Aerosol size and composition and meteorological data had previously been taken at ground locations at Tehachapi Pass and Rogers and China Lake dry lake beds in the summer of 1990. In the present work, the size distribution of dust particles and compositions of smog and dust aerosols were determined.

Professor **Andrés Larraza** is collaborating with the Remote Sensing Group at NRL, Stennis Center on shoaling waves. The collaboration consists in analyzing field data from the HAMLET's cove. Using a Hilbert transform technique and ray theory, celerity and general features of the bottom topography can be determined for HAMLET'S cove data. As ocean waves shoal, the wave field evolves substantially from its deep water state. For applications to ocean wave field data using Fourier transform, a dispersion relation between frequency and wavenumber has to be assumed in order to determine the phase velocity of the spectral components. On the other hand, using Hilbert transform on time series of a signal measured at different points, one can determine a relative phase shift and extract phase velocity measurements without reference to a dispersion relation. Celerity determination from filed data can have an important application to remote sensing.

### Weapons/Shipboard Systems Technologies

Professor **Baker** is working to develop and validate through laboratory and field measurements a numerical computer model of the PHALANX gun which can be used to quantify the effects of design changes and/or modifications on its performance. Forced harmonic vibration measurements on a PHALANX gun subassembly were performed in the laboratory. Measurements were made with and without the production muzzle restraint installed. Modal parameters (frequency, amplitude, mode shape) were obtained. These were used to validate and to improve the finite-element model of the PHALANX. A comparison was made between the computed and measured modal parameters. Good agreement was obtained. Including the muzzle restraint, it was not possible to obtain good agreement between experimental and finite-element results for modal parameters. It is suspected that this is due to "play" in the actual muzzle restraint mounting system, which is not modeled in the finite-element model.

Professor **Robert Keolian** numerically and analytically tested an acoustic energy concept for Anti-Submarine Warfare (ASW) applications. The idea was proposed by Edward Andrews of Tracor Applied. The concept modifies an AN/SQR-19 surface ship towed array with nonlinear elements. This would allow the detection of low frequency modulations of a signal transmitted by an AN/SQS-53C hull array. Ordinarily the two arrays work in different frequency bands. The addition of nonlinear elements to the towed array would allow the arrays to be used together for bistatic ASW. Many types of nonlinearities were modeled numerically, and found that in each case the concept would work as expected by Tracor in a noise free environment, but that there would be severe degeneration of the signal in the presence of noise, which would render the acoustic energy concept impractical. These results were verified analytically for a few of the possible nonlinearities.

Professor **Keolian** is also exploring how the physics of a mechanical structure influences the choice of a noise cancellation technique, in support of the design of the Conformal Array of Velocity Sensors (CAVES) fiber optic flank array on the hull of the new attack submarine. Vibration measurements were made at multiple locations on the USS Hartford (SSN 768) while in transit at various depths and speeds. The goal has been to predict the vibration waveform at a hull location from knowledge of the vibrations at the internal sources. Various adaptive and non-adaptive filters were used to predict the output from the input driving signal. While investigating the non-parametric methods of system identification, they found an apparently new way to improve the empirical transfer function estimate (ETFE).

Professors **Anthony Atchley**, **Steven Garrett**, **Thomas Hofler**, and **Robert Keolian** are working in the area of thermoacoustics. Thermoacoustics is an emerging technology that represents a feasible, non-CFC, non-global warming cooling alternative. During 1995, Professors Atchley, Hofler and Keolian began a collaboration to build a 1 kW heat driven cooler. The design, based on models developed by Professor Hofler, represents an order of magnitude increase in both cooling power and efficiency compared to previous heat driven coolers. The goal is to have a prototype built

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and tested by the end of FY 1996. This would allow a shipboard demonstration of heat driven cooler technology in FY 97. In addition to this collaboration, Professor Hofler worked on new heat exchanger designs using metal screens for stacks. Professor Keolian completed construction of the first pin stack, a design that offers the potential for a significant increase in overall efficiency. Professor Atchley worked on a toroidal prime mover, with the intent of understanding the onset of thermoacoustic prime movers in geometries without dominating boundary conditions. All of these efforts are aimed at improving the performance of thermoacoustic engines.

Professor **Steven Garrett** demonstrated mechanical driven, shipboard thermoacoustic cooling onboard the USS Deyo (DD-989). The cooler provided 419 W of cooling power to an equipment rack, maintaining the temperature within specifications. Professor Garrett is now on the faculty at Penn State.

## Ocean Acoustics and Air/Sea Interactions

Professor **Kevin Smith** worked on several projects concerning ocean acoustic propagation. The goal of one project was to upgrade an advanced acoustic propagation model for use with current and future research endeavors and to acquire a computer workstation capable of the CPU- and memory-intensive processing anticipated. A second project is to develop a theory on the effects of ocean mesoscale perturbations on adiabatic mode travel times. Confirmation of the theory will be in the form of numerical predictions obtained by a broadband, range-dependent parabolic equation model from which the field can be decomposed into local normal modes. The modeled ocean environment will be composed of a superposition of Rossby waves providing realistic mesoscale ocean features. The objective of a third project was to enhance understanding of the physics of long-range bottom reverberation in the context of low-frequency, active, underwater acoustics and successfully predict with numerical models the effects on current sonar systems. Another project involved work to understand the limits of signal resolution imposed by complex forward-propagating multipaths. The objective of another project is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight. Finally, he was involved with a study of the influence of the physics mismatch due to less-than-ideal acoustic ray model predictions on the localization of full-wave signals and with coordination of future research efforts towards a system demonstration of passive transient localization.

Professor **Steven Baker** is involved with research to experimentally validate a theory developed by scientists at the Naval Coastal Systems Station for the scattering of underwater sound from a porous solid sphere. The theory employs the Biot theory for the propagation of elastic waves in a fluid-filled porous solid and the T-matrix method for the multiple scattering of waves. The theory has potential application to the detection of mine-like objects buried in sediment.

Professor **Donald Spiel** is continuing a research project which involves the determination of the number of aerosols per unit time per unit area generated by oceanic processes, otherwise known as the ocean's aerosol source function. In the past year the effort to determine the birth of jet drops over the range of bubble sizes 350 to 1500  $\mu\text{m}$  radius was completed. The ejection speeds, time of ejection and the height at which all the jet droplets broke off the ascending jet were measured. Previously, the size distributions of these drops were determined. In addition, a theoretical solution to the problem of the number of film drops as a function of bubble size was advanced. Experiments were begun to test the efficacy of this theory.

## Combat Systems Technology and Policy

Professor **Joseph Sternberg** is working on projects involving applications of new methodologies for supporting C3I requirements and the assessment of the impact of information on tactical decision making.

Professor **Gordon Schacher** is working on modeling and simulation for combat systems in support of the Program Executive Office for Theater Air Defense.

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Professor **K.E. Woehler** is investigating the state of the technology and possible future capabilities of unattended ground sensor systems (UGS), with particular view toward their utility for tracking tactical missile launchers on the ground. Modern neural network processing of acoustic, seismic and magnetic signatures appears now to be capable of discriminating between vehicle types and the technology is being developed to air drop sensor fields that can communicate detections via satellite link to the shooters. This effort is funded by the Institute for Joint Warfare Analysis.

Professor **Xavier Maruyama** participated in activities related to the Office of Technology Assessment (OTA) project concerning technologies required for peacekeeping forces. The bulk of the effort was accomplished during the period he was on sabbatical residence at OTA. The project investigated available and potential technologies related to military operations other than war (MOOTW), including less-than-lethal weapons, landmines, defensive technologies, situational awareness technologies, and training and simulation issues.

### Mine Warfare

Professors **Donald Walters** and **Anthony Atchley** initiated research on mine detection and identification. Professor Walters' research concentrates on investigating and demonstrating the feasibility of high resolution imaging sonars for mine classification and identification. He is also investigating the possibility of using adaptive optics techniques to improve the image quality of high resolution sonars. Professor Atchley's research involves using surface waves to detect buried objects. An eventual goal is to combine the two projects and develop a synthetic aperture surface wave sonar for mine detection.

### Solid State Physics and Fundamental Processes

Professor **James Luscombe** is involved with a project to advance the state of the art in quantum device modeling. A wide variety of models are being developed for electrons in semiconductor nanostructures and associated issues related to the ultimate scaling of electronic devices. In addition, Professor Luscombe is developing models of the self-consistent electrostatic potential in quantum dot nanostructures as well as solutions to the Schrödinger equation in quantum wire geometries. Professor Luscombe is also working to develop models of the time-dependent, nonequilibrium elastic scattering structure factor for the investigation of strongly nonequilibrium processes in adsorbed surface overlayers.

Professor **Andrés Larraza** is establishing basic experimental and theoretical research in nonlinear waves. Two areas of research were covered: absorption of sound by noise with possible applications to the excess attenuation in a shallow water environment, and AM-FM conversion with applications to tunable lasers and high data rate fiber optic communications.

The Physics Department maintains and a linear electron accelerator (LINAC) and a flash x-ray machine. The facilities are used for classroom and research, especially by the Physics and Electrical and Computer Engineering Departments. The principal investigator for these facilities is Professor **Xavier Maruyama**, who collaborated on the E143 experiment, a major high energy experiment principally conducted at the Stanford Linear Accelerator Center. The Naval Postgraduate School LINAC played a crucial role in the creation of a polarized solid ammonium target. The E143 experiments constitutes the first ever contributions to Quantum Chromodynamics (quark physics) from the Naval Postgraduate School. This is the 31st year of continuous operation for the NPS LINAC. The group has re-established a means of doing dark current experiments at energies less than 60 million electron Volts, and are in the process of re-establishing the LINAC's capability as a source for classroom laboratory use. Other LINAC projects include radiation effects on electronics and investigation of parametric x-radiation.

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## Physics Laboratories

The physics laboratories are equipped to carry on research work in acoustics, electro-optics and IR technology, space and plasma physics, environmental physics, and directed-energy and radiation physics.

A 100-MeV electron linear accelerator with a 1- $\mu$ A-beam current has been used for nuclear-structure and radiation-damage experiments. Current research includes production of soft x rays by transition radiation and the production of coherent radiation by the stimulated Cherenkov effect.

A flash x ray (intensity exceeding  $5 \times 10^{10}$  R/sec) and electron accelerator system support studies of transient radiation effects. X-ray and electron transport codes are available.

The electro-optics laboratory uses imaging and detecting systems from the far-infrared to the visible range, including instrumentation for sea-going experiments in optical propagation. The laser laboratory contains a giant pulse laser and associated detection equipment for the visible spectrum and a high-power laser for the IR region.

The laser and plasma laboratory is equipped with high-speed oscilloscopes, plasma diagnostic probes, mass spectrographs, an optical spectrum analyzer, photographic equipment, and other lasers including a Q-switched Nd glass with monitoring accessories.

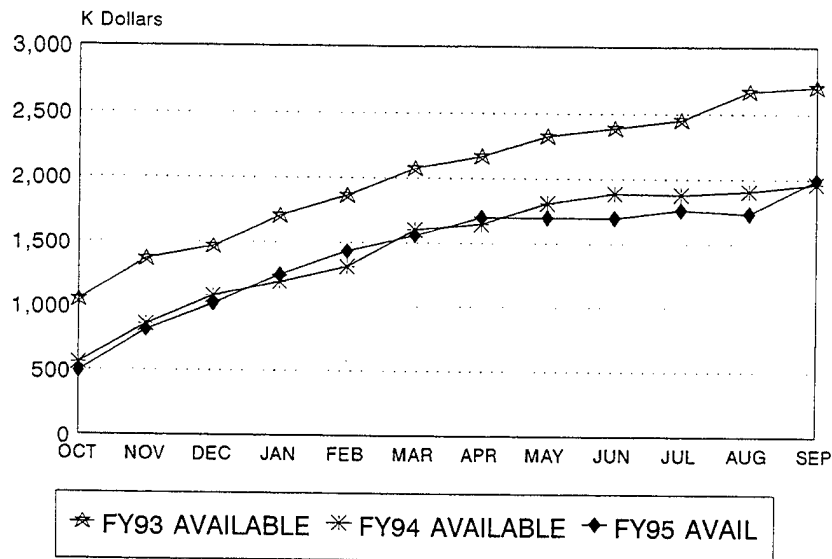
The acoustics laboratory equipment includes a large anechoic chamber and a multiple-unit acoustics laboratory for experimentation in airborne acoustics. Sonar equipment, test and wave tanks, anechoic water tanks, and instrumentation for investigation of underwater sound comprise the underwater acoustics laboratory. Facilities are also available for fabricating and testing thermo-acoustic refrigerators and sound sources, and for developing fiber-optic sensors (hydrophones, accelerometers, angle encoders) including lasers, fusion splicers, detectors, and extensive opto-electronic facilities for optical sensor demodulation and multiplexing.

The nuclear physics laboratory is equipped for experiments associated with the course in nuclear physics. Besides basic counters, instrumentation provides for alpha, beta, and gamma absorption measurements, nuclear spectroscopy with pulse-height analysis, and activation using the linear accelerator.

The Physics Department's Computational Physics and Simulation Laboratory contains ten Sun Sparcstation-2s with high-resolution color screens, a new CPU capacity of 224 million instructions per second (MIPS), 112 million floating point operations per second (Mflops), 4.0 Gbytes of hard-disk storage, and both high-resolution-color and black-and-white printers. The computers are connected by Ethernet to each other, the campus mainframe, and the outside world. The laboratory is used for instruction and research in the Physics Department.

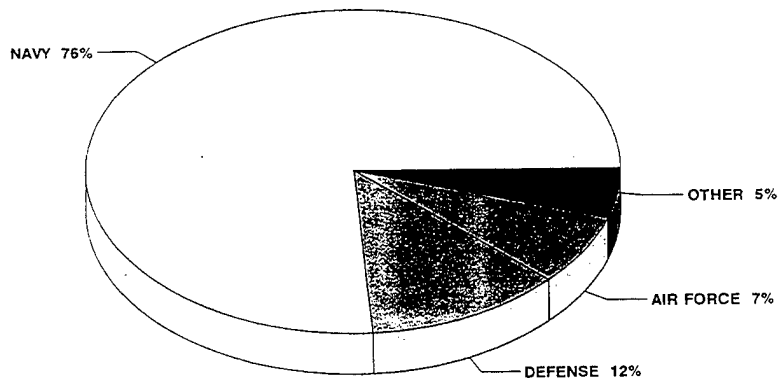
# FY95 REIMBURSABLE PROGRAM

## Department of Physics



**Figure 1. Reimbursable Funds Available by Fiscal Year.**

This graph shows the amount of reimbursable funding available to the department. Dollar amounts include research and academic reimbursable activities.



**Figure 2. FY95 Reimbursable Sponsor Profile.**

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## BASIC RESEARCH IN THERMOACOUSTIC HEAT TRANSPORT

Anthony A. Atchley, Associate Professor

Department of Physics

Sponsor: Office of Naval Research

**OBJECTIVE:** The overall objective of this research is to investigate mechanisms that place fundamental limitations on the high amplitude performance of thermoacoustic engines. Specific tasks include the design of a heat driven refrigerator capable of cooling powers in the 1000 W range, and investigations of a toroidal prime mover.

**SUMMARY:** During the second part of FY 1995, a close collaboration was started with Professors Tom Hofler and Robert Keolian to design and build a heat driven thermoacoustic cooler capable of 1000 W heat loads with an overall heat input to cooling power conversion efficiency of approximately 50%. Both the cooling power and the efficiency represent an order of magnitude increase over previous Wheatley heat driven coolers. The basic design tool is a computer program developed by Professor Hofler. The cooler has been designed and is being fabricated. Results are expected in the second half of FY 96.

One possible configuration for a 1 KW cooler is to have two 500 W coolers arranged in a toroidal resonator. An important distinction between this design and conventional designs is that there is no point in the toroid that imposes dominating boundary conditions, such as found at the rigid end of a typical thermoacoustic engine. An appropriate question is whether or not this configuration will work. During FY 95, investigations began on toroidal prime movers, with the intention of answering some of the questions that arise from the configuration. This work is continuing.

### PUBLICATION:

Kordomenos, J., Atchley, A.A., Raspet, R., and Bass, H.E., "Experimental Study of a Thermoacoustic Termination of a Traveling-wave Tube," Journal of Acoustical Society of America, Vol. 98, pp. 1623-1628, 1995.

### CONFERENCE PRESENTATION:

Atchley, A.S., "Hot Topics in Physical Acoustics," 130th Meeting of the Acoustical Society of America, Journal of Acoustical Society of America, Vol. 98, No. 5, Pt. 2, St. Louis, MO, p. 2935(A), November 1995.

### THESIS DIRECTED:

Yang, M. S., "Design of a Toroidal Thermoacoustic Prime Mover," Master's Thesis, June 1995.

**DOD KEY TECHNOLOGY AREA:** Other (Energy Conversion)

**KEYWORDS:** Thermoacoustic, refrigeration, cooler

## EXPERIMENTAL INVESTIGATION OF THE SCATTERING OF UNDERWATER SOUND FROM A POROUS SOLID SPHERE

Steven R. Baker, Associate Professor

Department of Physics

Sponsor: Naval Postgraduate School

**OBJECTIVE:** The objective is to experimentally validate a theory developed by scientists at the Naval Coastal Systems Station for the scattering of underwater sound from a porous solid sphere.



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**SUMMARY:** Drs. Raymond Lim and Steve Kargl (formerly) of the Naval Coastal Systems Station have developed a theory for the scattering of elastic waves from a fluid-filled porous solid obstacle embedded in a fluid-filled porous solid host. Their theory employs the Biot theory for the propagation of elastic waves in a fluid-filled porous solid and the T-matrix method for the multiple scattering of waves. The theory has potential application to the detection of mine-like objects buried in sediment.

In previous years, two porous solid sphere samples of nominal diameter two inches were obtained, composed of nominal 100- and 500-micron diameter bonded glass beads, respectively. Physical properties such as porosity, permeability, and shear modulus were measured for cylindrical samples manufactured at the same time as the spherical samples. An unusually small value of 0.14 for the Poisson's ratio was observed (the Poisson's ratio of the borosilicate glass of which the beads are composed is 0.2). The values obtained for the cylindrical samples were assumed for the spherical samples in calculating the expected acoustic scattering. Bistatic underwater acoustic scattering measurements were made on the spherical samples as a function of angle and frequency in the underwater acoustic tanks at NPS. The range of frequency covered was approximately 30 kHz to 150 kHz. Experimental results obtained for the 100-micron sample were in reasonably good agreement with theoretical results, especially at the lower frequencies, except for a consistent deficit in the measured backscatter. Agreement between the results for the 500-micron sample was poor, probably due to sample inhomogeneity.

While visiting l'Institut Supérieur d'Electronique du Nord (ISEN), Lille, France, for a month in FY95, Professor Baker had the opportunity to repeat some of the underwater scattering measurements on the 100-micron sample in their new tank facility, which is much larger and capable of making much more precise measurements than at NPS. Monostatic backscattering measurements were made over the frequency range 10 kHz to 60 kHz. Excellent agreement with theoretical predictions was found in certain frequency subranges, especially near response peaks observed at 14 kHz and 58 kHz; good or fair agreement was found in the remainder. Bistatic scattering measurements (into the rear hemisphere) were made at 14 kHz, 30 kHz, and 58 kHz. Very good to excellent agreement was found between the predicted and measured scattering as a function of angle at 14 kHz and 58 kHz. As observed in the data taken at NPS, the 30 kHz measurements showed a deficit in the backscatter direction compared to theoretical predictions, but excellent agreement for large scattering angles.

## CONFERENCE PRESENTATION:

Pace, M.E., Huskey, T.W.L, Baker, S.R., Kargl, S.G., and Lim, R., "Bistatic Scattering of Underwater Sound from a Porous Solid Sphere: A Comparison of Theory and Experiment," 129th Meeting of the Acoustical Society of America, Journal of Acoustical Society of America, Vol. 97, p. 3422, 30 May - 3 June 1995.

**DOD KEY TECHNOLOGY AREAS:** Other (Mine Countermeasures, Littoral Warfare)

**KEYWORDS:** Underwater acoustics, porous media acoustics, Biot theory, T-Matrix

## STRUCTURAL DYNAMICS OF THE PHALANX GUN

Steven R. Baker, Associate Professor

Department of Physics

Sponsors: Naval Surface Warfare Center - Port Hueneme Detachment  
and Naval Postgraduate School

**OBJECTIVE:** The goal of this project is to develop and validate through laboratory and field measurements a numerical computer model of the PHALANX gun which can be used to quantify of the effects of design changes and/or modifications on its performance.

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**SUMMARY:** The PHALANX close-in weapon system (CIWS) provides close-in ship defense against incoming missiles. The CIWS attempts to destroy a sea-skimming missile at a range where missile fragments are not likely to damage the ship. Reducing bullet angular dispersion can significantly increase the system's ability to destroy targets at long range. Using finite-element modeling, it was shown by previous NPS students and colleagues that the dynamical oscillations of the rotating six-barrel PHALANX gun can be an important contribution to dispersion.

For a Masters thesis research project, forced harmonic vibration measurements were formed on a PHALANX gun subassembly in the laboratory. Swept-sine measurements were made for frequencies from 5 Hz to 125 Hz, spanning the most important frequency range of barrel oscillations. A shaker was used to apply a vertical or horizontal force to a barrel tip, and the resulting acceleration response was measured at up to eleven locations on the gun and its housing. Static axial barrel loading (set-back) was applied for all measurements to simulate that which occurs during a firing. Measurements were made with and without the production muzzle restraint installed. Modal parameters (frequency, amplitude, mode shape) were obtained. These were used to validate and to improve the finite-element model of the PHALANX gun, the subject of a Master's thesis.

Another thesis ported the previously-developed finite-element model of the PHALANX gun from ANSYS version 4.4a to ANSYS version 5.0. Using this model, modal parameters were computed for the PHALANX gun, first without the muzzle restraint and then with. The critical stiffnesses which most influence the modal frequencies, the ball-bearing, needle-bearing, and ball joint stiffnesses, were adjusted in the model to obtain the best agreement with the measured modal frequencies without the muzzle restraint. A comparison was then made between the computed and measured modal parameters. Good agreement was obtained. Including the muzzle restraint, it was not possible to obtain good agreement between experimental and finite-element results for modal parameters. It is suspected that this is due to "play" in the actual muzzle restraint mounting system, which is not modeled in the finite-element model.

## **THESIS DIRECTED:**

Guzman, C. and Gaffe, J., "Correlation of Experimental and Finite-Element Modal Analysis of the PHALANX M61A1 Close-In Weapons System," Master's Thesis, December 1995.

**DOD KEY TECHNOLOGY AREA:** Conventional Weapons

**KEYWORDS:** PHALANX, Close-In Weapons System (CIWS), structural dynamics, vibration, modal analysis

## **A NEW TECHNIQUE FOR REMOTE SENSING OF TRACE GASES**

**David D. Cleary, Associate Professor**

**Department of Physics**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** The goal of this project was to develop a passive technique for remote sensing the ionospheric electron density profile on a global basis. Specifically, to determine if the electron density can be inferred from the ultraviolet signature of the positive ions in the ionosphere.

**SUMMARY:** During 1995, significant progress was made on the development of a new technique for remote sensing of trace gases. The most notable was the progress we made on the development of the NPS All-Reflection Michelson interferometer. The design of this instrument was conceived in 1993 and a prototype was tested using a HeNe laser. During 1994, a prototype using incoherent visible sources was demonstrated. During 1995, the detector was modified to operate in the ultraviolet. A UV image intensifier tube was added to the CCD camera. Using this modified detector, the operation of this instrument was successfully demonstrated in the UV using the Mercury 2537-Å emission. In 1995 a detailed computer algorithm was also developed that performs the coherent summing and transformation of the

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interferogram to produce the observed Hg line profile. In addition to instrument development, an analysis of the  $O^+$  834-Å emission was conducted to determine the feasibility of its use in ionospheric remote sensing. It was found that for nearly all altitudes this emission is sufficiently bright for this application.

## **PUBLICATION:**

Cleary, D.D., Gnanalingam, S., McCoy, R.P., Dymond, K.F., and Eparvier, F.G., "The Middle Ultraviolet Dayglow Spectrum," Journal of Geophysical Research, Vol. 100, p. 9729, 1995.

## **CONFERENCE PRESENTATIONS:**

Cleary, D. D. and Hicks, J.D., "A New Technique for Measuring Atomic Oxygen in the Earth's Thermosphere," American Geophysical Union 1995 Spring Meeting, Baltimore, MD, 30 May - 2 June 1995.

Dymond, K.F., McCoy, R.P., Thonnard, S.E., Budzien, S.A., Cleary, D.D., Bullet, T., and Thomas, R.J., "Preliminary Results of the 1992 Flight of the High Resolution Airglow and Aurora Spectrograph (HIRAAS) Experiment," American Geophysical Union 1995 Fall Meeting, San Francisco, CA, 11-15 December 1995.

## **THESES DIRECTED:**

Leloudas, F., "Development of Ground Support Equipment for the NPS Ionospheric Spectroscopy and Atmospheric Chemistry (ISAAC) Ultraviolet Spectrograph," Master's Thesis, June 1995.

Hicks, J.D., "Design, Development and Testing of the All-Reflection Michelson Interferometer (AMI) for use in the Mid-ultraviolet Region," Master's Thesis, December 1995.

## **DOD KEY TECHNOLOGY AREA: Sensors**

**KEYWORDS:** Ionospheric electron density, ultraviolet spectroscopy

## **RESEARCH IN SPATIALLY MULTIPLEXED IMAGING AND MULTISPECTRAL IMAGING**

**David S. Davis, Associate Professor**

**Department of Physics**

**Sponsor: Program Executive Office - Theater Air Defense**

**OBJECTIVE:** This is a continuing, multi-year project which has as its primary goal the development of a proof-of-concept prototype instrument capable of recording fully multiplexed images and multispectral images at long infrared wavelengths, where efficient focal plane array technology is not available.

**SUMMARY:** FY95 represented the third year's activity on this project, which is nominally expected to comprise about five years' effort to develop a working prototype. Most of this year's work centered around the CAD refinement of the designs for the reflecting-transmitting Walsh function basis masks and their optical substrates, and in interacting closely with the principal contractor and subcontractors who fabricated the actual devices to the specifications. There were several technical surprises that appeared during the fabrication process, most of them related to mechanical stability and optical surface quality issues. These problems had not been anticipated by either the Principal Investigator or the contractors. With the expenditure of very substantial effort on the part of all concerned, the encoding mask systems were fabricated successfully, albeit in a larger format than was called for in the original plans for the instrument. This is requiring a rescaling of the prototype instrument's geometry and optics, and represents a significant slippage (about 6 - 8 months at the time of this writing) of our originally proposed schedule for time to completion and proof-of-concept

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demonstration. Such unexpected glitches are not unreasonable in the development cycle of a new technology, as represented by this project. Indeed, this is probably inevitable whenever the limits of technology are being pushed, as is the case in state-of-the-art research. These delays should not impede the further development of multiplexed imaging systems, however, because the contractors/manufacturers are now confident that the technical demands of future systems can be handled, now that the initial systems have been successfully fabricated. At the close of 1995, the requisite modifications to the optical and opto-mechanical designs of the prototype instrument were being conducted. This effort is being carried over into 1996.

## **PUBLICATION:**

Davis, D.S., "Multiplexed Imaging by Means of Optically-generated Kronecker Products: 1. the Basic Concept," Applied Optics, Vol. 34, pp. 1170-1176, 1995.

## **CONFERENCE PRESENTATION:**

Cleary, D.D., Hicks, J.D., and Davis, D.S., "A New Technique for Measuring Atomic Oxygen in the Earth's Thermosphere," Eos Transactions, American Geophysical Union, Supplement 76, p. S207, 1995.

## **THESIS DIRECTED:**

Rangel, C., "Evaluation of Optical System Designs" Master's Thesis, December 1995.

**DOD KEY TECHNOLOGY AREAS:** Sensors, Electronics

**KEYWORDS:** Sensors, infrared, passive remote sensing

## **IMPROVED EFFICIENCY AND POWER DENSITY FOR THERMOACOUSTIC COOLERS**

**Thomas J. Hoffer, Research Associate Professor**

**Department of Physics**

**Sponsor: Office of Naval Research**

**OBJECTIVE:** To perform basic research on thermoacoustic cooling processes for applications requiring high cooling power and a small temperature span. Such applications could include cooling onboard Navy ships or commercial refrigeration and air-conditioning.

**SUMMARY:** It was previously shown that short heat exchangers with very fine fin structure can perform much more efficiently in engines having very high acoustic amplitude. The following research was performed in 1995.

The new heat exchangers require metal fin spacings on the order of 100 microns. The fabrication process has been perfected and several have been produced. Some have been made of copper in both small and large diameters, while others have been made of entirely of nickel for use in high temperature thermoacoustic drivers.

Much work has been done on the heat driven cooling engine. The engine is a high cooling power, high reliability device having no moving parts. The new design has been modeled more extensively and precisely. The model predicts an overall system COP (cooling power/heat input) of 43%. With this model, sound onset stability conditions have also been investigated.

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The stability/onset criteria appears to be extremely sensitive to the resonator temperature distribution. While this may be somewhat difficult to control properly, it is seen as a potential solution to the otherwise severe problem of starting the heat driven cooler with its cold-end at ambient temperatures, without adding moving parts.

The model has been scaled up to 35 KW of cooling power, in a package of modest size. The model predicts an overall COP of about 0.75 without detailed optimization. It is expected that the COPs in the range of 1.0 can be obtained, which is competitive with current absorption cooler technology. Absorption technology also requires undesirable chemicals such as ammonia and lithium bromide. A heat driven cooler of this size would be suitable for cooling a structural compartment of a Navy ship, possibly using waste heat as a power source.

Parts for a 1 KW experimental unit are mostly fabricated and expected to have performance data this fiscal year. Some promising performance data on a new "stack" structure for the high temperature driver also exists. Another high temperature stack structure is being looked at in conjunction with Lawrence Livermore National Laboratory.

Earlier in the year the experimental work on our cryocooler project was wrapped-up. A best temperature span of 123° C below room temperature was obtained, which is a new record for thermoacoustic coolers. More importantly, the measurements proved that Stirling cycle concepts can be applied to thermoacoustic engines to good effect.

## **PUBLICATION:**

Hofler, T.J., "Improved Efficiency and Power Density for Thermoacoustic Coolers," Naval Postgraduate School Technical Report, NPS-PH-96-001, October 1995.

## **CONFERENCE PRESENTATIONS:**

Hofler, T.J. and Adeff, J.A., "Experimental Results from Four Thermoacoustic Cryocoolers," Journal of Acoustical Society of America, Vol. 98, No. 5, Pt. 2, p. 2960, St. Louis, MO, November 1995.

Hofler, T.J., "Thermoacoustic Refrigeration," Fluid Mechanics Seminar, Stanford University, 11 April 1995.

**DOD KEY TECHNOLOGY AREA:** Other (Energy Conversion)

**KEYWORDS:** Thermoacoustic, refrigeration, cooler

**THERMOACOUSTIC PIN STACKS**  
**Robert M. Keolian, Assistant Professor**  
**Department of Physics**  
**Sponsor: Office of Naval Research**

**OBJECTIVE:** The primary objective of this continuing research project is to construct and test "pin stacks." This stack geometry is predicted to substantially improve the efficiency of thermoacoustically based refrigerators, heat pumps and prime movers.

**SUMMARY:** With the aid of a winding jig that has gone through many modifications, a pin stack has been constructed by hand sewing a football field length of constantan wire back and forth 2310 times an inch and a half at a time in a hexagonal lattice between the hot and cold heat exchangers of a thermoacoustic prime mover. The wire diameter is 75 microns with a lattice spacing of 750 microns.

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From computer modeling (with the program DeltaE) it was learned that the pin stack is considerably more sensitive than a conventional flat plate stack to changes in parameters—such as stack element spacing or size, mean operating pressure or temperature. This was verified analytically by expanding the pin stack solution for transport of Swift and Keolian in the appropriate limit of small pins. Heat transport and thermoacoustic work depend quadratically on the thermal penetration depth in this limit, while the conventional flat plate stack depends linearly on the penetration depth.

In collaboration with Hofler, Atchley, Adeff, and students, the Principal Investigator helped in the construction of a large heat driven thermoacoustic refrigerator, with the ultimate aim of using waste heat from Navy ship exhaust as the drive.

## **THESIS DIRECTED:**

Nessler, F.S., "Comparison of a Pin Stack to a Conventional Stack in a Thermoacoustic Prime Mover," Master's Thesis, December 1994.

## **PATENT:**

Keolian, R.M. and Swift, G.W., "Thermoacoustic Pin Stack," U.S. Patent No. 5,456,082, October 1995.

**DOD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles - Ships and Watercraft, Environmental Quality, Materials, Processes and Structures

**KEYWORDS:** Refrigeration, thermoacoustics, cooling, pin stack

## **CAVES FLANK ARRAY AND SELF NOISE**

Robert M. Keolian, Assistant Professor

Department of Physics

Daphne Kapolka, LCDR, US Navy

Sponsor: Naval Sea Systems Command

**OBJECTIVE:** To explore how the physics of a mechanical structure influences the choice of a noise cancellation technique, in support of the design of the Conformal Array of Velocity Sensors (CAVES) fiber optic flank array on the hull of the New Attack Submarine.

**SUMMARY:** Vibration measurements were made at multiple locations on the USS Hartford (SSN 768) while in transit at various depths and speeds. The goal has been to predict the vibration waveform at a hull location from knowledge of the vibrations at the internal sources. To help clarify how factors such as dispersion, damping, transmission time, multi-path transmission, mode conversion, and noise influence the performance of various noise cancellation techniques, simple vibrating systems of bars and plates were investigated. Various adaptive and non-adaptive filters were used to predict the output from the input driving signal. While investigating the non-parametric methods of system identification, an apparently new way to improve the empirical transfer function estimate (ETFE) was found.

## **CONFERENCE PRESENTATION:**

Keolian, R.M. and Barlow, C., "Cancellation of Self-Noise by Direct Sensing of Principal Sources," Meeting of CAVES Design/Signal Processing Working Group, Arlington, VA, 12 July 1995.

**DOD KEY TECHNOLOGY AREAS:** Sensors, Surface/Under Surface Vehicles-Ships and Watercraft, Computing and Software, Modeling and Simulation

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**KEYWORDS:** New Attack Submarine, sonar, self noise, sensor, noise cancellation, CAVES, transfer function, system identification

## FUNDAMENTAL ASPECTS OF NONLINEAR WAVES

Andrés Larraza, Assistant Professor

Department of Physics

Sponsor: Naval Postgraduate School

**OBJECTIVE:** To establish basic experimental and theoretical research in nonlinear waves. Two areas of research were covered: Absorption of sound by noise with possible applications to the excess attenuation in a shallow water environment, and AM-FM conversion with applications to tunable lasers and high data rate fiber optic communications.

**SUMMARY:** In regard to the absorption of sound by noise, a small amplitude signal in the presence of high intensity broad band noise attenuates due to nonlinear interaction with the noise. If the noise is isotropic, the attenuation is exponential. If the interaction is restricted to be in one dimension, the attenuation coefficient has been predicted to be a linear function of position; that is, the amplitude of the signal attenuates as a *gaussian*. These results can have applications in the determination of the attenuation of a signal in a shallow water environment. During 20-27 March 1995 Professor Bruce Denardo from the University of Mississippi and the Principal Investigator successfully conducted experiments to measure the attenuation of sound in air as a result of absorption by noise in one dimension in a high intensity traveling wave tube.

In regard to AM-FM conversion, the Principal Investigator has predicted that in a nonlinear dispersive medium, when the product of the dispersion and the nonlinear coefficient is positive a signal that is amplitude modulated at the source will become frequency modulated at periodic positions in space. These results can have applications in an all-optical AM-FM conversion and in high data rate fiber optic communications. These results were applied to typical parameters in Erbium-doped fiber and shown that for a 0.1 W source operating at a frequency of  $5.8 \times 10^{14}$  Hz and a 50% amplitude modulation of  $10^{10}$  Hz in a  $10 \mu\text{m}^2$  fiber, the distance for AM-FM conversion is about 20 m in doped glasses. The corresponding FM frequency spectrum has a range of about  $3.5 \times 10^{14}$  Hz. Thus an amplitude modulated green light alternating between bright and dim at the source will alternate between red and blue at a rate of  $10^{10}$  Hz at a location of about 20 m down the fiber. This mechanism allows the possibility of tunable phased-locked coherent light from a single frequency coherent source.

### PUBLICATION:

Denardo, B. and Larraza, A., "Far Off Equilibrium Acoustic Phenomena," Proceedings of the 1994 Physical Acoustic Summer School, pp. 306-357, 1995.

### OTHER:

Larraza, A., Denardo, B., and Atchley, A., "Absorption of Sound by Noise in One Dimension," submitted for publication to Journal of Acoustical Society of America.

Larraza, A. and Denardo, B., "Investigations of Nonlinear Acoustic Noise," document submitted to ONR for funding consideration.

**DOD KEY TECHNOLOGY AREA:** Environmental Quality

**KEYWORDS:** Nonlinear waves, random waves, nonlinear fiber optics

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## SHOALING WAVES

Andrés Larraza, Assistant Professor

Department of Physics

Sponsor: Naval Research Laboratory

**OBJECTIVE:** To perform research on dynamics of shoaling water waves. Using a Hilbert transform technique and ray theory, celerity and general features of the bottom topography can be determined for HAMLET'S cove data.

**SUMMARY:** As ocean waves shoal, the wave field evolves substantially from its deep water state. For applications to ocean wave field data using Fourier transform, a dispersion relation between frequency and wavenumber has to be assumed in order to determine the phase velocity of the spectral components. On the other hand, using Hilbert transform on time series of a signal measured at different points, one can determine a relative phase shift and extract phase velocity measurements without reference to a dispersion relation. Celerity determination from field data can have an important application to remote sensing. Current collaboration with the Remote Sensing Group at National Research Laboratory, Stennis Space Center consists of analyzing field data from the HAMLET'S cove.

### OTHER:

Larraza, A. and Smith, P., "Determination of Phase Velocity from Field Data Using the Hilbert Transform" in preparation.

**DOD KEY TECHNOLOGY AREA:** Environmental Quality

**KEYWORDS:** Shoaling waves, bottom topography, remote sensing

## DEVELOPMENT OF QUANTUM DEVICE MODELS

James H. Luscombe, Associate Professor

Department of Physics

Sponsor: Naval Postgraduate School

**OBJECTIVE:** The objective of this project is to advance the state of the art in quantum device modeling.

**SUMMARY:** Development continued on a wide variety of models for electrons in semiconductor nanostructures and associated issues related to the ultimate scaling of electronic devices. A simple electrostatic model of field-effect transistor structures that emphasizes the basic issues in continued down-scaling of conventional device structures was formulated and analysis begun. This model involves the use of conformal mapping techniques combined with numerical solutions of the Laplace equation. New numerical methods for the accurate evaluation of Fermi-Dirac integrals, which are an essential part of modeling quantum devices with heavily doped regions so that the electrons form a degenerate electron gas, were devised. The method combines the use of exact series expansion representations of Fermi-Dirac integrals together with numerical series acceleration techniques. Development of high-precision numerical methods for the solution of the time-dependent Schrödinger equation for use in modeling Bloch oscillations in semiconductor superlattices as well as a high-precision numerical method for the accurate evaluation of the quantum-mechanical electron transmission coefficient was undertaken.

### PUBLICATION:

Luscombe, J.H., "Modelling Bloch Oscillations," Proceedings of the Third International Semiconductor Device Research Symposium, p. 683, 1995.



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## **CONFERENCE PRESENTATION:**

Luscombe, J.H., "Modelling Bloch Oscillations," International Semiconductor Device Research Symposium, Charlottesville, VA, December 1995.

**DOD KEY TECHNOLOGY AREA:** Other (Nanoelectronics)

**KEYWORDS:** Nanoelectronic modeling, Terahertz radiation, Quantum Transport in Superlattices

## **ADVANCED QUANTUM DEVICE SIMULATOR DEVELOPMENT**

**James H. Luscombe, Associate Professor**

**Department of Physics**

**Sponsor: Texas Instruments, Inc.**

**OBJECTIVE:** The objective of this project is to develop realistic computer simulation tools for resonant tunneling diodes.

**SUMMARY:** This project was begun in late September 1995, with an initial presentation made to Texas Instruments in October 1995. An account with the Maui High Performance Computing Center (MHPCC) was established to support this project under the DoD National High Performance Computing Modernization Program (HPCMP). Initial device simulation codes were ported to the parallel computing environment of the MHPCC; initial simulations were run with results reported to Texas Instruments.

## **OTHER:**

Presentation at Texas Instruments, Inc., J.H. Luscombe, "Use of Supercomputers in Nanoelectronic Modeling," October 1995, Dallas, TX.

**DOD KEY TECHNOLOGY AREA:** Other (Nanoelectronics)

**KEYWORDS:** Nanoelectronic modeling, resonant tunneling diodes

## **MODEL QUANTUM-EFFECT SEMICONDUCTOR DEVICES**

**James H. Luscombe, Associate Professor**

**Department of Physics**

**Sponsor: Naval Command, Control and Ocean Surveillance Center**

**OBJECTIVE:** The objective of this project is to develop models of the self-consistent electrostatic potential in quantum dot nanostructures as well as solutions to the Schrödinger equation in quantum wire geometries.

**SUMMARY:** This project, while awarded in October 1995, was not funded until late in the year.

**DOD KEY TECHNOLOGY AREA:** Other (Nanoelectronics)

**KEYWORDS:** Nanoelectronic modeling, quantum wire devices

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## **NONEQUILIBRIUM STATISTICAL PHYSICS: APPLICATIONS TO DISORDERING OF ADSORBED SURFACE MONOLAYERS**

**James H. Luscombe, Associate Professor**

**Department of Physics**

**Sponsor: Unfunded**

**OBJECTIVE:** The objective of this project is to develop models of the time-dependent, nonequilibrium elastic scattering structure factor for the investigation of strongly nonequilibrium processes in adsorbed surface overlayers.

**SUMMARY:** This project was initiated this year out of curiosity driven research. Developed exact one-dimensional model for nonequilibrium structure factor upon a sudden change in temperature; believed to be the first exact solution of the structure factor in which the number of particles is conserved. Solved exactly a model of dynamic critical phenomena in one dimension that underscores the use and pitfalls of finite-size scaling theory at second-order phase transitions.

### **OTHER:**

Talk at Iowa State University, J.H. Luscombe, "Nonequilibrium structure factor for the disordering adsorbed monolayers," Ames, IA, September 1995.

**DOD KEY TECHNOLOGY AREA:** Other (Surface Science)

**KEYWORDS:** Surface diffusion, advanced materials

## **FACILITIES SUPPORT FOR THE LINEAR ACCELERATOR (LINAC) AND FLASH X-RAY MACHINE**

**Xavier K. Maruyama, Professor**

**Richard Harkins, LCDR, USN**

**Department of Physics**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** This project is to maintain the electron accelerator facilities at the Naval Postgraduate School. The facilities are used for classroom and research use especially by the Physics and Electrical and Computer Engineering Departments.

**SUMMARY:** The LINAC especially has been a productive workhorse as exemplified by the publications appearing this past year. The E143 experiment is a major high energy experiment principally conducted at the Stanford Linear Accelerator Center with the Naval Postgraduate School LINAC playing a crucial role in the creation of a polarized solid ammonium target. Professor Sherif Michael of the ECE department reports in his summary concerning radiation effects on electronics. The experimental work was conducted at the LINAC. Work in investigation of parametric x-radiation continues with worldwide recognition as evidenced by the conference presentation in Tomsk, Russia. The LINAC is the only source available for creating radioactivity for the nuclear physics course laboratory experiment.

The multi-authored E143 experiments constitutes the first ever contributions to Quantum Chromodynamics (quark physics) from the Naval Postgraduate School. This is the 31st year of continuous operation for the NPS LINAC. Present emphasis is to repair a damaged klystron. Commercial-off-the shelf costs are \$130,000, but cost effective repair means using surplus equipment from other accelerators is being pursued. A means of doing dark current experiments at energies less than 60 million electron volts was reestablished. Re-establishing its capability as a source for classroom laboratory use is in progress.

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## PUBLICATIONS:

K.Abe, T. Akagi, P.L. Anthony, R. Antonov, R.G. Arnold, T. Averett, H.R. Band, J.M. Bauer, H. Borel, P.E. Bosted, V. Breton, J. Button-Shafer, J.P. Chen, T.E. Chupp, J. Cledenin, C. Comptour, K.P. Coulter, G. Court, D. Crabb, M. Daoudi, D. Day, F.S. Dietrich, D. Day, F.S. Dietrich, J. Dunne, H. Dutz, R. Erbacher, J. Fellbaum, A. Feltham, H. Fonvieille, E. Friez, D. Garvey, R. Gearhart, J. Gomez, P. Grenier, K.A. Griffioen, S. Hoibraten, E.W. Hughes, C. Hyde-Wright, J.R. Johnson, D. Kawall, A. Klein, S.E. Kuhn, M. Kuriki, R. Lindgren, T.J. Liu, R.M. Lombard-Nelsen, J. Marroncle, T. Maruyama, **X.K. Maruyama**, J. McCarthy, W. Meyer, Z.E. Meziani, R. Minehart, J. Mitchell, J. Morgenstern, G.C. Petratos, R. Pitthan, D. Pocanic, C. Prescott, R. Prepost, P. Raines, B. Raue, D. Reyna, A. Rijllart, Y. Roblin, L. Rochester, S.E. Rock, O.A. Rondon, I. Sick, L.C. Smith, T.B. Smith, M. Spengos, F. Staley, P. Steiner, S. St.Lorant, L.M. Stuart, F. Suekane, Z.M. Szalata, H. Tang, Y. Terrien, T. Usher, D. Walz, J.L.K. White, K. Witte, C. Young, B. Youngman, H. Yuta, G. Zapalac, B. Zihlmann, D. Zimmerman, (The E143 Collaboration), "Precision Measurement of the Proton Spin Structure Function  $g_1^p$ ," Physical Review Letters, Vol. 74, p. 346, 1995.

K.Abe, T. Akagi, P.L. Anthony, R. Antonov, R.G. Arnold, T. Averett, H.R. Band, J.M. Bauer, H. Borel, P.E. Bosted, V. Breton, J. Button-Shafer, J.P. Chen, T.E. Chupp, J. Cledenin, C. Comptour, K.P. Coulter, G. Court, D. Crabb, M. Daoudi, D. Day, F.S. Dietrich, D. Day, F.S. Dietrich, J. Dunne, H. Dutz, R. Erbacher, J. Fellbaum, A. Feltham, H. Fonvieille, E. Friez, D. Garvey, R. Gearhart, J. Gomez, P. Grenier, K.A. Griffioen, S. Hoibraten, E.W. Hughes, C. Hyde-Wright, J.R. Johnson, D. Kawall, A. Klein, S.E. Kuhn, M. Kuriki, R. Lindgren, T.J. Liu, R.M. Lombard-Nelsen, J. Marroncle, T. Maruyama, **X.K. Maruyama**, J. McCarthy, W. Meyer, Z.E. Meziani, R. Minehart, J. Mitchell, J. Morgenstern, G.C. Petratos, R. Pitthan, D. Pocanic, C. Prescott, R. Prepost, P. Raines, B. Raue, D. Reyna, A. Rijllart, Y. Roblin, L. Rochester, S.E. Rock, O.A. Rondon, I. Sick, L.C. Smith, T.B. Smith, M. Spengos, F. Staley, P. Steiner, S. St.Lorant, L.M. Stuart, F. Suekane, Z.M. Szalata, H. Tang, Y. Terrien, T. Usher, D. Walz, J.L.K. White, K. Witte, C. Young, B. Youngman, H. Yuta, G. Zapalac, B. Zihlmann, D. Zimmerman, (The E143 Collaboration), "Measurement of the Proton and Deuteron Spin Structure Function  $g_2$  and Asymmetry  $A_2$ " to appear in Physical Review Letters, 1995.

K.Abe, T. Akagi, P.L. Anthony, R. Antonov, R.G. Arnold, T. Averett, H.R. Band, J.M. Bauer, H. Borel, P.E. Bosted, V. Breton, J. Button-Shafer, J.P. Chen, T.E. Chupp, J. Cledenin, C. Comptour, K.P. Coulter, G. Court, D. Crabb, M. Daoudi, D. Day, F.S. Dietrich, D. Day, F.S. Dietrich, J. Dunne, H. Dutz, R. Erbacher, J. Fellbaum, A. Feltham, H. Fonvieille, E. Friez, D. Garvey, R. Gearhart, J. Gomez, P. Grenier, K.A. Griffioen, S. Hoibraten, E.W. Hughes, C. Hyde-Wright, J.R. Johnson, D. Kawall, A. Klein, S.E. Kuhn, M. Kuriki, R. Lindgren, T.J. Liu, R.M. Lombard-Nelsen, J. Marroncle, T. Maruyama, **X.K. Maruyama**, J. McCarthy, W. Meyer, Z.E. Meziani, R. Minehart, J. Mitchell, J. Morgenstern, G.C. Petratos, R. Pitthan, D. Pocanic, C. Prescott, R. Prepost, P. Raines, B. Raue, D. Reyna, A. Rijllart, Y. Roblin, L. Rochester, S.E. Rock, O.A. Rondon, I. Sick, L.C. Smith, T.B. Smith, M. Spengos, F. Staley, P. Steiner, S. St.Lorant, L.M. Stuart, F. Suekane, Z.M. Szalata, H. Tang, Y. Terrien, T. Usher, D. Walz, J.L.K. White, K. Witte, C. Young, B. Youngman, H. Yuta, G. Zapalac, B. Zihlmann, D. Zimmerman, (The E143 Collaboration), "Measurement of the  $Q^2$ -dependence of the Proton and Deuteron Spin Structure Functions  $g_1^p$  and  $g_1^d$ ," Physics Letters, Vol. B364, pp 61-68, 1995.

K.Abe, T. Akagi, P.L. Anthony, R. Antonov, R.G. Arnold, T. Averett, H.R. Band, J.M. Bauer, H. Borel, P.E. Bosted, V. Breton, J. Button-Shafer, J.P. Chen, T.E. Chupp, J. Cledenin, C. Comptour, K.P. Coulter, G. Court, D. Crabb, M. Daoudi, D. Day, F.S. Dietrich, D. Day, F.S. Dietrich, J. Dunne, H. Dutz, R. Erbacher, J. Fellbaum, A. Feltham, H. Fonvieille, E. Friez, D. Garvey, R. Gearhart, J. Gomez, P. Grenier, K.A. Griffioen, S. Hoibraten, E.W. Hughes, C. Hyde-Wright, J.R. Johnson, D. Kawall, A. Klein, S.E. Kuhn, M. Kuriki, R. Lindgren, T.J. Liu, R.M. Lombard-Nelsen, J. Marroncle, T. Maruyama, **X.K. Maruyama**, J. McCarthy, W. Meyer, Z.E. Meziani, R. Minehart, J. Mitchell, J. Morgenstern, G.C. Petratos, R. Pitthan, D. Pocanic, C. Prescott, R. Prepost, P. Raines, B. Raue, D. Reyna, A. Rijllart, Y. Roblin, L. Rochester, S.E. Rock, O.A. Rondon, I. Sick, L.C. Smith, T.B. Smith, M. Spengos, F. Staley, P. Steiner, S. St.Lorant, L.M. Stuart, F. Suekane, Z.M. Szalata, H. Tang, Y. Terrien, T. Usher, D. Walz, J.L.K. White, K. Witte, C. Young, B. Youngman, H. Yuta, G. Zapalac, B. Zihlmann, D. Zimmerman, (The E143 Collaboration), "Precision Measurement of the Deuteron Spin Structure Function  $g_1^d$ ," Physical Review Letters, Vol. 75, p. 25, 1995.

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## CONFERENCE PRESENTATIONS:

Fiorito, R.B., Rule, D.W., Buckingham, W., Ivey, L., DiNova, K., Maruyama, X.K., and Piestrup, M.A., "Absolute Spectral and Angular Distribution Measurements of Parametric X-radiation in Graphite Crystals with Varying Degrees of Mosaicity," 2nd International Symposium on Radiation from Relativistic Electrons in Periodical Structures, Tomsk, Russia, 4-8 September 1995

Maruyama, X.K., "The Effect of Mosaic Structure on Parametric X-radiation," Department of Physics Colloquium, Catholic University, Washington, DC, 25 January 1995.

## THESES DIRECTED:

Stamatopoulos, V., "Plasma Formation on the Anode of the Flash X-Ray Facility," Master's Thesis, March 1995.

Barrows, J., "High Order Parametric X-Radiation from Silicon and Lithium Fluoride Crystal Monochromators," Master's Thesis, December 1995.

**DOD KEY TECHNOLOGY AREA:** Other (Radiation Effects)

**KEYWORDS:** Parametric radiation, x-ray, LINAC

## TECHNOLOGY REQUIRED FOR PEACEKEEPING FORCES

Xavier K. Maruyama, Professor

Department of Physics

Sponsor: Office of Technology Assessment, United States Congress

**OBJECTIVE:** The principal investigator participated in all activities related to the Office of Technology Assessment (OTA) project concerning Technologies Required for Peacekeeping Forces. The bulk of the effort was accomplished during the period in which the Principal Investigator was on sabbatical residence at OTA. The project investigated available and potential technologies related to Military Operations Other than War (MOOTW), including Less-than-Lethal Weapons, Landmines, Defensive Technologies, Situational Awareness Technologies, and Training and Simulation Issues.

**SUMMARY:** Less-than-Lethal Weapons Technologies included, anti-personnel and anti-material weapons, technologies applicable to law enforcement, conventional crowd control and information warfare. The landmine study concentrated on demining capabilities included infrared detectors, ground penetrating radars, acoustic detection, metal detection, dogs, x- and gamma-ray detectors and other aids such as mine classification data bases. Defensive technologies described sniper and countersniper technologies, rifleman accuracy improvements, projectile locator radars, body armor, and light vehicle armor. Situational awareness technologies discussed soldier locators, unattended ground sensors, PSYOP related technologies such as population identification and crowd estimation and unmanned air vehicles.

## PUBLICATION:

Maruyama, X.K., "Improving the Prospects for Future International Peace Operations," workshop proceedings, Background Paper, OTA-BP-ISS-167, 136 pages, September 1995.

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## CONFERENCE PRESENTATIONS:

Maruyama, X.K., "Doing Physics Outside of Physics," Department of Physics Colloquium, Naval Postgraduate School, Monterey, CA, 6 October 1996 and Department of Physics and Chemistry REU Program, University of Virginia, July 14, 1995 and Department of Physics Seminar, Tulane University, New Orleans, VA, 13 September 1996.

Maruyama, X.K., "Landmines," Carl Menneken Mine Warfare Lecture, Undersea Warfare Academic Group, Naval Postgraduate School, Monterey, CA, 26 October 1995.

Maruyama, X.K., "Peacekeeping Technologies," OTA presentation to the North Atlantic Assembly, U.S. Senate, Washington, DC, 13 June 1995.

Maruyama, X.K., "The Bowman-Venneri Effect," Department of Physics Workshop for Science Teachers, University of Virginia, 26 July 1995.

Maruyama, X.K., "Landmines," presentation to the Chief of Naval Operations Strategic Study Group Conference, Innovation and Naval Technology 2020, Asilomar and Naval Postgraduate School, Monterey, CA, 20 December 1995.

## OTHER:

Book Review of Dark Sun, The Making of the Hydrogen Bomb by Richard Rhodes, X.K. Maruyama, to appear in Naval War College Review, Spring 1996.

Full publication of the results of the study begun at the Office of Technology Assessment will be completed under sponsorship of another agency. Publication media under consideration include Naval War College Review.

**DOD KEY TECHNOLOGY AREA:** Other (Radiation Effects)

**KEYWORDS:** Parametric radiation, x-ray

## AEROSOL CHARACTERISTICS OF THE WESTERN MOJAVE DESERT

Richard C. Olsen, Associate Professor

Phillip L. Walker, Physicist

Department of Physics

Sponsor: Naval Air Warfare Center - Weapons Division

**OBJECTIVE:** To analyze and examine for correlations aerosol and meteorological data taken at Edwards Air Force Base and the Naval Air Warfare Center - Weapons Division, China Lake in 1990.

**SUMMARY:** Aerosol size and composition and meteorological data had previously been taken at ground locations at Tehachapi Pass and Rogers and China Lake dry lake beds in the summer of 1990. In the present work the size distribution of dust particles and compositions of smog and dust aerosols were determined. Smog particle (0-2.5  $\mu$ ) concentrations by mass were found to be 50% organic carbon, 17% elemental carbon while the expected sulfates and nitrates make up the rest. However, the organic material may actually be vapors which have condensed on the filters masquerading as particles. Further measurements will be needed to determine the nature of the organics. The dust particles were found to be composed of illite clay plus trace elements. The size of dust particles was found not to depend on wind speed. Increasing wind speed was found to cause more dust particles to be in the atmosphere, at least at Edwards Dry Lake where dust mass is wind speed independent up to 7 m/s and thereafter is exponentially related to wind speed by  $m = 0.55 \exp(0.59u)$ . At China Lake atmospheric dust was greatest when the air was still, decreasing

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up to 4 m/s, and wind speed nearly independent up to 10 m/s. These characteristics are significantly different from the dust model in LOWTRAN7/MODTRAN. The optical properties of the dust model and the data are different enough to warrant changing the model. However, additional data is needed for wind speeds greater than 10 m/s. A working research report is in progress and due to the sponsor in June.

## **PUBLICATION:**

Walker, P.L. and Mathews, L.A., "Optical Characteristics of Desert Dust as Used in LOWTRAN: Mojave Desert Dust Versus the LOWTRAN 7 Dust Model," SPIE Proceedings, p. 2471, 1995.

## **CONFERENCE PRESENTATION:**

Walker, P.L. and Mathews, L.A., "Optical Characteristics of Desert Dust as Used in LOWTRAN: MOJAVE Desert Dust Versus the LOWTRAN 7 Dust Model," SPIE Conference on Atmospheric Propagation and Remote Sensing IV Orlando, FL, April 1995.

**DOD KEY TECHNOLOGY AREAS:** Environmental Quality, Other (Electro-Optical Systems)

**KEYWORDS:** Infrared transmittance, desert aerosols, weather

## **CONFIGURATION OF COMPUTATIONAL PLATFORM FOR DATA ANALYSIS AND MODEL PREDICTIONS OF UNDERWATER ACOUSTIC PROPAGATION**

**Kevin B. Smith, Assistant Professor**  
**Department of Physics**  
**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** The goal of this project was to upgrade an advanced acoustic propagation model brought to the Naval Postgraduate School by Professor Smith for use with current and future research endeavors and to acquire a computer workstation capable of the CPU- and memory-intensive processing anticipated.

**SUMMARY:** While at the University of Miami from 1988 to 1992, Professor Smith worked closely with Professor Fred Tappert in the development of an advanced underwater acoustic propagation model now referred to as the University of Miami Parabolic Equation (UMPE) model. Since that time, Professor Smith has maintained and upgraded the UMPE model for different computer systems and various research objectives. During the past year, a new multi-processor computer workstation with significant memory has been purchased and configured. While this was being accomplished, the computer code for UMPE was upgraded to incorporate fully 3-dimensional refractive effects (to be contrasted with the typical 2-D by N approaches of most current models). This numerical method and some results were presented as an invited paper at the Second International Conference on Theoretical and Computational Acoustics in Honolulu, Hawaii in August of 1995. Also, an algorithm has been incorporated to generate real-time visualizations of acoustic propagation and an example of this was also presented at the conference in Honolulu.

## **PUBLICATION:**

Smith, K.B., "Modeling the Effects of Azimuthal Coupling on Acoustic Propagation in the Presence of 3-Dimensional, Rough Ocean Interfaces Using the Parabolic Approximation," Proceedings of Second International Conference on Theoretical and Computational Acoustics, August 1995.

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## CONFERENCE PRESENTATIONS:

Smith, K.B., "Modeling the Effects of Azimuthal Coupling on Acoustic Propagation in the Presence of 3-Dimensional, Rough Ocean Interfaces Using the Parabolic Approximation," Second International Conference on Theoretical and Computational Acoustics, August 1995.

Smith, K.B., "Time Domain Animation of Spatial Acoustic Propagation Using Standard CW PE Modeling Techniques," Second International Conference on Theoretical and Computational Acoustics, 1995.

## THESIS DIRECTED:

Kaemmerer, G., "Simulation of Acoustic Multipath Arrival Structure in the Middle Atlantic Bight," Master's Thesis, June 1995.

**DOD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Computing and Software

**KEYWORDS:** UMPE model, acoustic propagation, azimuthal coupling, multi-processor

## EFFECTS OF OCEAN MESOSCALE FEATURES ON ADIABATIC MODE TRAVEL TIMES

Kevin B. Smith, Assistant Professor  
Department of Physics  
Sponsor: Naval Postgraduate School

**OBJECTIVE:** The objective of this work is to develop a theory on the effects of ocean mesoscale perturbations on adiabatic mode travel times. Confirmation of the theory will be in the form of numerical predictions obtained by a broadband, range-dependent parabolic equation model from which the field can be decomposed into local normal modes. The modeled ocean environment will be composed of a superposition of Rossby waves providing realistic mesoscale ocean features.

**SUMMARY:** The use of adiabatic normal mode theory is justifiable in environments containing slowly modulating, range-dependent perturbations. In such cases, the calculation of the field response due to an active source measured at some distant range is greatly simplified since coupling between modes is considered negligible. The amplitudes of the local modes only in the vicinity of the source and receiver need to be computed while the effect of the range dependence is accounted for simply by integrating the horizontal modal wavenumber along the propagation path. Computing the excitation of the modes by the source then provides the relative amplitudes of the modes at any range regardless of how they adjust to the local environment. However, while such environments may not affect relative modal amplitudes, slowly modulating sound speed perturbations may still affect mode travel times over long distances. A theoretical model of the effect on mode travel times due to a superposition of baroclinic Rossby waves will be developed. The predictions can then be compared to results obtained from a broadband, range-dependent parabolic equation model from which the field can be decomposed into local normal modes. The effects on tomography or source localization in the presence of such an environment will also be discussed. A generalized, statistical description of the travel time effect can then be developed and compared with predictions made employing an advanced eddy-resolving ocean dynamics model.

## THESIS DIRECTED:

Amy R. Smith "Effect of Ocean Mesoscale Features on Adiabatic Mode Travel Times," Master's Thesis, June 1995.

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## OTHER:

Smith, A.R., Smith, K.B., and Chiu, C.-S., "Effect of Ocean Mesoscale Features on Adiabatic Mode Travel Times," submitted for Proceedings of the 3rd European Conference on Underwater Acoustics. Forthcoming June 1996.

**DOD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Environmental Quality

**KEYWORDS:** Acoustic pulse propagation, adiabatic modes, ocean mesoscale features

## BOTTOM REVERBERATION DATA ANALYSIS

Kevin B. Smith, Assistant Professor

Department of Physics

Sponsor: Scripps Institution of Oceanography and Office of Naval Research

**OBJECTIVE:** The goal of this project was to enhance our understanding of the physics of long-range bottom reverberation in the context of low-frequency, active, underwater acoustics and successfully predict with numerical models the effects on current sonar systems.

**SUMMARY:** High quality acoustic reverberation data was collected during the Acoustic Reverberation Special Research Program's (ARSRP) main acoustics cruise in the summer of 1993. This project, sponsored by the Office of Naval Research, focused on the analysis of this data. It has been shown that large-scale reverberation returns correlate well with large-scale bathymetric features. This research has confirmed this but has also shown that the resolution of such returns becomes degraded by complex multipath structures resulting in multiple arrivals in the time domain.

Confirmation of these arrivals from various measurements within the ARSRP data set has been accomplished. Over the past year, these multipath effects have been studied more thoroughly and quantified. This research was the focus of the master's thesis of Erick Cushman. It is intended to submit a portion of this work for publication in the near future. The influence of azimuthal, out-of-plane propagation was also studied and these results were presented at an ONR sponsored conference in Woods Hole, MA, in July of 1995. Finally, the total influence of propagation will be subtracted from the reverberation data, resulting in a map of scattering strengths over the entire ARSRP area.

## PUBLICATION:

Smith, K.B., Hodgkiss, W.S., and Tappert, F.D., "Propagation and Analysis Issues in the Prediction of Long-Range Reverberation," Journal of the Acoustical Society of America, to appear March 1996.

## CONFERENCE PRESENTATION:

Smith, K.B., "Effects of Azimuthal Coupling on Long-range (1 1/2 CZ) Reverberation," ONR-ARSRP Symposium, Woods Hole, MA, 19-21 July 1995.

## THESIS DIRECTED:

Cushman, E.B., "Bottom Backscatter Mapping: the Effect of Secondary Multipath Interactions," Master's Thesis, December 1995.

**DOD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (environmental effects, acoustic reverberation, sonar performance)



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**KEYWORDS:** Acoustic reverberation, propagation, multipaths, azimuthal coupling

## **BOTTOM REVERBERATION DATA ANALYSIS AND PROPAGATION MODELING OF COMPLEX MULTIPATHS**

**Kevin B. Smith, Assistant Professor**

**Department of Physics**

**Sponsor: Office of Naval Research**

**OBJECTIVE:** The scientific objective of this work is to understand the limits of signal resolution imposed by complex forward-propagating multipaths. This will be studied in both deep and shallow water environments with data from the 1993 ARSRP acoustics cruise used to compare deep water results. Proposed here is a two-year program involving data analysis, model predictions, and the software development to support and improve both.

**SUMMARY:** High quality acoustic reverberation data was collected during the Acoustic Reverberation Special Research Program's (ARSRP) main acoustics cruise in the summer of 1993. The ability to correlate these measured returns with bathymetric features depends on the signal resolution. A study of the effects of multipath propagation on signal resolution is proposed. Analysis of the measured data will provide a means of confirming predictions of these effects. An advanced PE propagation model will be used to quantify these effects in the ARSRP environment. Incorporating shallow water databases will provide a means of studying similar effects in a littoral environment. This research is a continuation of the FY95 research sponsored jointly by ONR and the Scripps Institution of Oceanography. Erick B. Cushman graduated in Dec., 1995, and the core of his thesis is currently being re-written for publication.

### **THESES DIRECTED:**

Cushman, E.B., "Bottom backscatter mapping: the effect of secondary multipath interactions," Master's Thesis, December 1995.

Yuan, M.-C. "The effects of shallow water bottom interface roughness and volume fluctuations on broadband pulse resolution," Master's Thesis, December 1995.

**DOD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (environmental effects, acoustic reverberation, sonar performance)

**KEYWORDS:** Acoustic reverberation, propagation, multipaths, azimuthal coupling

## **AN EXAMINATION OF 3D, BROADBAND ACOUSTIC PROPAGATION PHYSICS IN A LITTORAL OCEAN ENVIRONMENT - AN EXTENSION TO AN OFFICE OF NAVAL RESEARCH PRIMER FIELD STUDY IN THE MID-ATLANTIC BIGHT**

**Kevin B. Smith, Assistant Professor**

**Department of Physics**

**Ching-Sang Chiu, Professor**

**Department of Oceanography**

**Sponsor: Office of Naval Research**

**OBJECTIVE:** The scientific objective of this work is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight.

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**SUMMARY:** With the emphasis of USW shifting to littoral environments, the understanding and, ultimately, prediction of acoustic propagation in the vicinity of the shelf break becomes increasingly important. The sloping bathymetry, the extreme seasonal changes in the vertical sound-speed structure and the significant horizontal variability generated by the shelf-break front are just a few of the environmental factors that make this problem both interesting and complex. Under the PRIMER initiative, the Office of Naval Research is sponsoring a multi-year study of acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream. The general purpose of this project is to study the effects of the frontal region on acoustic propagation onto the shelf. This research is a complementary study of propagation effects and data analysis. Specifically, the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions shall be addressed. In addition to the experimental components already in place, the deployment of explosive SUS charges throughout the area at the beginning and end of the study is being coordinated. The addition of these very broadband sources will provide valuable information on specific frequency dependent phenomena. In preparation for the shallow water acoustic modeling that will be required to achieve these goals, the UMPE acoustic model which was developed with Professor Fred Tappert of the University of Miami has been upgraded. Recent work together is being published as an invited book chapter.

## **THESIS DIRECTED:**

D'Agostino, A.F., "Simulation of 3-D acoustic arrival structure in the Middle Atlantic Bight and its effect on the inverse tomography solution," Master's Thesis, December 1995.

**DOD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Environmental Quality

**KEYWORDS:** Acoustic pulse propagation, azimuthal coupling, continental slope, internal waves, ocean front

## **EXAMINATION OF PHYSICS MISMATCH INFLUENCE ON LOCALIZATION**

**Kevin B. Smith, Assistant Professor**

**Department of Physics**

**Ching-Sang Chiu, Professor**

**Department of Oceanography**

**Sponsor: Naval Undersea Warfare Center, New London Detachment**

**OBJECTIVE:** The scientific objective of this work is to study the influence of the physics mismatch due to less-than-ideal acoustic ray model predictions on the localization of full-wave signals and to coordinate future research efforts towards a system demonstration of passive transient localization.

**SUMMARY:** A study of issues relating to the localization of passive transients is being coordinated by the Naval Undersea Warfare Center - New London. This research focuses on an examination of the influence of physics mismatch in the prediction of the acoustic propagation. A signal autocorrelation matching algorithm is used to produce the ambiguity surface for the localization. A full-wave, parabolic equation model is employed to produce a synthetic signal and a reciprocal prediction to provide a baseline for the mismatch. Predictions from a ray model based on the same parabolic approximation are then matched to the synthetic signal. By comparing this ambiguity surface with the baseline, the influence of the physics mismatch due to ray predictions can be quantified. Several aspects of the ray model (e.g., phase and amplitude information) can be independently affected providing information on model degradation of localization performance. In addition to the scientific research involved in this project, the Principal Investigator is also being tasked with the coordination of the larger program of passive transient localization. Additional responsibilities include coordinating the direction and interaction of various researchers towards a common goal of producing a working system capable of being employed by the fleet.

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**DOD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Sensors, Other (Localization)

**KEYWORDS:** Parabolic equation model, Hamiltonian ray model, matched field, transient localization

## **BURSTING BUBBLES AND THE AEROSOL SOURCE FUNCTIONS**

**Donald E. Spiel, Research Associate Professor**

**Department of Physics**

**Sponsor: Office of Naval Research**

**OBJECTIVE:** This is a continuing research project the purpose of which is to determine the ocean's aerosol source function. That is, to determine how many aerosols per unit time per unit area are generated by oceanic processes.

**SUMMARY:** In the past year the effort to determine the birth of jet drops over the range of bubble sizes 350 to 1500  $\mu\text{m}$  radius was completed. The ejection speeds, time of ejection and the height at which all the jet droplets broke off the ascending jet measured. Previously, the size distributions of these drops were determined. In addition, a theoretical solution to the problem of the number of film drops as a function of bubble size was advanced. Experiments were begun to test the efficacy of this theory.

### **PUBLICATION:**

Spiel, D.E., "On the Births of Jet Drops from Bubbles Bursting on Water Surfaces," Journal of Geophysical Research, Vol. 100, pp. 4995-5006, 1995.

### **OTHER:**

The following articles were submitted to The Journal of Geophysical Research during the reporting period:

Spiel, D.E., "A Hypothesis Concerning the Peak in Film Drop Production as a Function of Bubble Size."

Spiel, D.E., "More on the Births of Jet Drops from Bubbles Bursting on Sea Water Surfaces."

**DOD KEY TECHNOLOGY AREA:** Environmental Quality

**KEYWORDS:** Aerosol, source function, bubbles

## **ASSESSMENT OF THE IMPACT OF CHANGES IN INFORMATION ON TACTICAL DECISION MAKING**

**Joseph Sternberg, Professor**

**Ross S. Thackeray, Research Professor**

**Department of Physics**

**Sponsor: Office of the Secretary of Defense, Director of Net Assessment**

**OBJECTIVE:** This work has been part of a continuing project. The objective of this program has been to develop and apply a new methodology for assessing the impact of tactical intelligence and surveillance systems on the mission success of a naval carrier battle group. The need to account for operational decisions based on conflicting and incomplete information has led to the development of a unique wargame for the methodology.

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**SUMMARY:** An important aspect of the wargame is the incorporation of models in the wargame that provide a simulation of offensive and defensive engagements. The parameters in these models can be varied to represent current or future capabilities. The parameters we have been using have been reviewed with navy experts in these areas to assure credibility for our representation. A series of "sensitivity" tests using these simulations have been carried out to determine the quantitative impact on offensive and defensive operations of faulty intelligence on the enemy.

Progress has been made in identifying the enemy actions that could degrade, confuse, or limit the non-organic information flow with a potential impact on tactical decisions. Working contact has been established with the DIA and with the CNA to arrive at a plausible picture as to what could reasonably be done by the "enemy" considering his level of technology, equipments that might be available on the world market, and consulting advice from knowledgeable third parties.

A series of briefing of this program were made to the offices in OPNAV and JCS responsible for determining the requirements for tactical intelligence and surveillance systems and information warfare to acquaint them with the potential of this methodology to help provide answers to key issues.

**PUBLICATION:**

Sternberg, J., Thackeray, R., and Johnson, F., "A New Methodology for Assessing the Military Value of Tactical Intelligence and Surveillance Systems," Naval Postgraduate School Technical Report, NPS-PH-95-001, May 1995.

**OTHER:**

Numerous working papers have been prepared covering various aspects of the methodology, the non-organic information flow, and player preparation.

**DOD KEY TECHNOLOGY AREA:** Other (Information Warfare)

**KEYWORDS:** Information warfare, wargame, tactical intelligence requirements

## ATMOSPHERIC OPTICAL TURBULENCE IN SUPPORT OF THE US AIR FORCE AIRBORNE LASER PROGRAM

Donald L. Walters, Associate Professor

Department of Physics

Sponsor: US Air Force Phillips Laboratory

**OBJECTIVE:** Turbulence within the stratosphere restricts, severely, the energy density needed to destroy a theater missile in flight during the boost phase. Accurate measurements are critical for the potential development of a theater missile defense system.

**SUMMARY:** NPS had the responsibility of developing a single probe, centimeter resolution, .001K noise level, stratospheric probe system, and fly the equipment in conjunction with the Airborne Laser Atmospheric Compensation Experiment that started in March 1995. A probe package, balloon telemetry link and data reduction software were developed and deployed during the March 1995 and McConnell AFB, Wichita Kansas. The high resolution probe show sharp temperature increases of 0.5 to 1 K over 1-2 m. These sharp temperature jumps are sufficiently abrupt to degrade the performance of laser systems with similar aperture sizes by introducing much higher beam wander and jitter than anticipates. The results of this effort were presented to the USAF Phillips Laboratory in October 1995. A modeling effort is underway to determine if impact of the measurements.

# PHYSICS

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## **CONFERENCE PRESENTATION:**

Walters, D.L., "Stratospheric Atmospheric Turbulence Balloon Measurements in Support of the Airborne Laser Program," ABL-ACE experiment, Kirtland Air Force Base, NM, October 1995.

**DOD KEY TECHNOLOGY AREA:** Other (Theater Missile Defense)

**KEYWORDS:** Lasers, laser propagation, laser weapons, atmospheric turbulence

## **NAVAL POSTGRADUATE SCHOOL MINE COUNTERMEASURES PROGRAM**

**Donald L. Walters, Associate Professor**

**Department of Physics**

**Sponsor: US Naval Program Executive Office, Mine Warfare**

**OBJECTIVE:** To initiate a Mine Warfare program at NPS that includes, courses, a Mine Warfare Chair and faculty/student research in areas critical to USN Mine Countermeasures.

**SUMMARY:** The purpose of this program was to initiate a comprehensive mine warfare (MIW) program at NPS which includes faculty/student research, course development and presentation and a MIW Chair. The Chair's responsibilities include organizing a MIW lecture series, producing a newsletter to the MIW community, organizing MIW workshops, and initial planning for the second MIW symposium scheduled to occur at NPS in November 1996. The research activities concentrated on investigating and demonstrating feasibility of high resolution imaging sonars for mine classification and identification.

## **THESIS DIRECTED:**

Welter, J. D., LT, USN, "High Resolution Synthetic Aperture Sonar," Master's Thesis, December 1995.

**DOD KEY TECHNOLOGY AREA:** Other (Mine Warfare)

**KEYWORDS:** Sonar, synthetic aperture

**1995**

**Faculty Publications  
and  
Presentations**

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